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STRATIGRAPHY OF THE GREEN RIVER FORMATION IN THE BRIDGER BASIN, WYOMING¹

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INTRODUCTION

This paper presents the results of a subsurface-surface stratigraphic study of the lacustrine Green River Formation and related strata in the Bridger Basin of southwestern Wyoming. Although the Green River Formation has been mapped in some detail, and several geologists have worked on the shore and near-shore facies in areas bordering the basin, no detailed subsurface study of the formation has so far appeared. The Diamond Alkali Co. No. 3 well was chosen as a type well since it displayed all the surface stratigraphic units in core or cuttings, and electric log. Surface sections and other wells were then correlated with it.

PREVIOUS STUDIES

Reconnaissance studies of the Green River Formation in the Bridger Basin began with the Territorial Surveys of Powell, Hayden, and King from 1868 to 1878. No detailed stratigraphic work was attempted until Schultz (1920) mapped the Rock Springs Uplift and adjacent areas. Green River nomenclature was expanded or revised by Sears and Bradley (1924), Bradley (1926, 1959, 1961), Donovan (1950), Deardorff (1959), and Culbertson (1962).

Several geologists have studied the shore and near-shore phases of the Green River Formation. Donovan (1950) and Oriel (1961) worked on the northwest outcrop, McGrew and Berman (1955) in the north, and Bradley (1926) in the northeast. Sears and Bradley (1924), Anderman (1955), Deardorff (1959), Millice (1959), and Culbertson (1961) studied the relationships in the southeastern part of the basin.

Love et al. (1955), Blackstone (1955), and Bradley (1961) have published geologic maps of the area. Important contributions by Bradley on varves, origin of oil shale, the Green River climate, and other topics have been published.

Since the discovery of the evaporite mineral shortite ($\text{Na}^2\text{CO}^3 \cdot 2\text{CaCO}^3$) by Fahey (1939), many papers and abstracts have appeared dealing with the description and genesis of the unique mineral assemblage of the Green River Formation. Complete bibliographies may be found in Milton and Eugster (1959) and Fahey (1962). Winchester (1923) and Deardorff (1959) have reported on some of the oil shales along the eastern outcrop. Love (1955) and Love and Milton (1959) described several uraniferous zones.

LOCATION AND GEOLOGIC SETTING

The Bridger Basin is located in the extreme southwestern part of Wyoming, and extends a few miles into northeastern Utah (fig. 1). It is essentially triangular

¹Adapted from part of a thesis presented in partial fulfillment of the requirements for the degree Master of Science in the Graduate School of The Ohio State University, 1960.

in shape, with the east-west trending Uinta Mountains at the base. The western leg of the triangle consists of the Wyoming Range and the hogbacks formed by the Darby and Absaroka overthrusts. The Rock Springs Uplift and the Wind River Mountains form the eastern boundary, and the Gros Ventre Mountains are at the apex of the triangle. This study is concerned with the southern two-thirds of the basin, in which the Green River Formation was deposited.

The Early and Middle Eocene Green River Formation lies nearly everywhere on the Early Eocene Wasatch Formation, but in some areas overlaps pre-Wasatch rocks. Much of the Green River Formation is overlain by the Middle or Late(?)

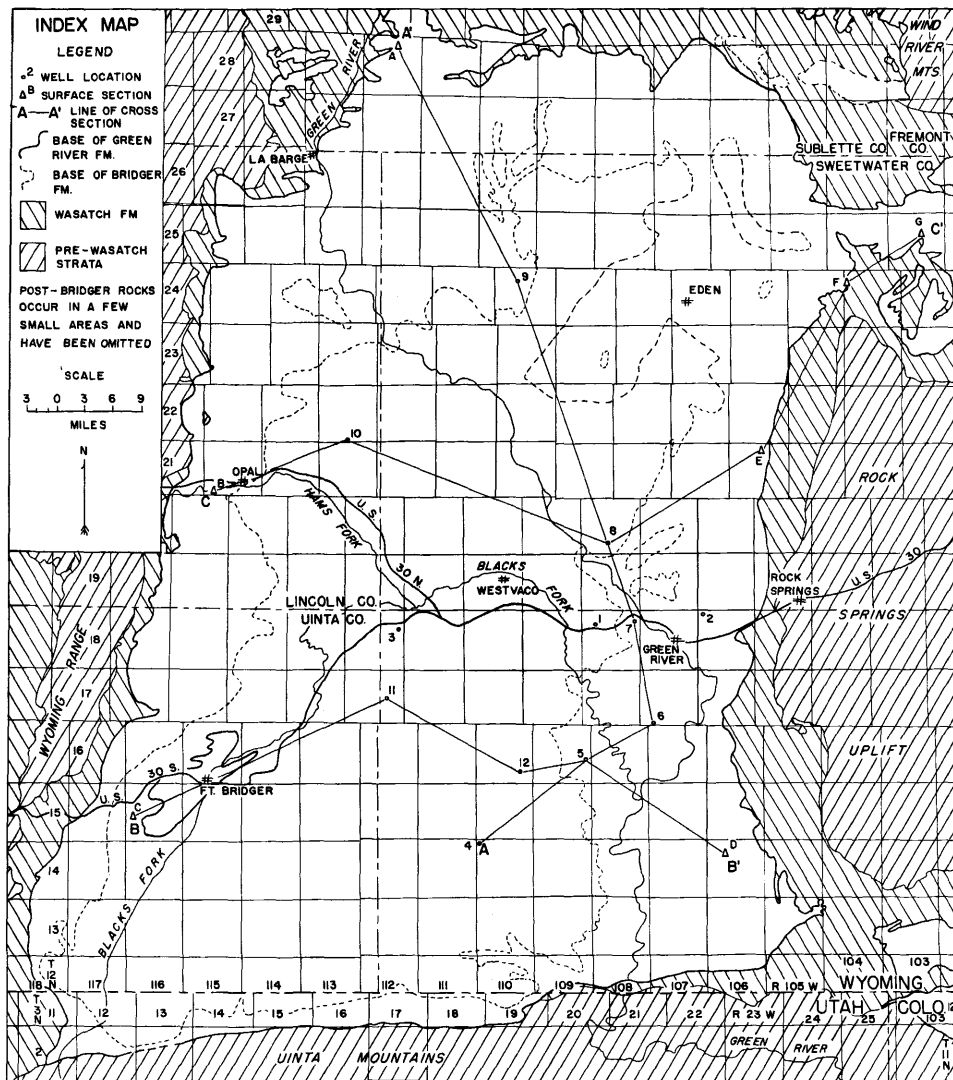


FIGURE 1. Index map of the Bridger Basin showing the locations of surface sections and wells, lines of cross sections, and general geology of the Bridger Basin and surrounding areas. The geology is modified after Love et al. (1955), Blackstone (1955), and Bradley (1961).

Eocene Bridger Formation. The highlands that surround the basin are composed of crystalline and sedimentary rocks which range in age from Precambrian to Paleocene. The Bridger Basin is both a topographic and a structural basin, and the Green River Formation dips gently basinward and forms conspicuous escarpments along most of its outcrop. The southern, western, and northern outcrops are essentially marginal deposits denoting the original areal extent of the Green River beds, whereas the eastern outcrop is erosional and exposes typical lacustrine rock.

STRATIGRAPHY
Nomenclature

The Green River Formation was named by Hayden (1873), from outcrops in the vicinity of the town of Green River, Wyoming. The name was applied to thinly laminated chalky shales of lacustrine origin. Three years later, Powell (1876) divided the formation into the Upper and Lower Groups, with his Tower Sandstone forming the base of the Upper Group. Since then, the nomenclature has undergone extensive revision (fig. 2).

HISTORY OF NOMENCLATURE												
HAYDEN 1873	POWELL 1876	SCHULTZ 1920	BRADLEY 1926		DONAVAN 1950	BRADLEY 1959			DEARDORFF 1959	THIS REPORT		
EAST	EAST	EAST	EAST	NORTHEAST	NORTHWEST	N.W. & WEST	EAST	NORTHEAST	SOUTHEAST	N.W. & WEST	EAST	NORTHEAST
BRIDGER GROUP	BRIDGER GROUP	BRIDGER FORMATION	BRIDGER FORMATION		BRIDGER FORMATION	BRIDGER FORMATION			BRIDGER FORMATION	BRIDGER FORMATION		
GREEN RIVER SHALES	UPPER & R. GROUPS	PLANT BEDS	PLANT BEDS	MORROW CREEK MEMBER	MORROW CREEK MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER
	TOWER SS	TOWER SANDSTONE	TOWER SS LENTIL	MORROW CREEK MEMBER	MORROW CREEK MEMBER	LANEY SHALE MEMBER	TOWER SS LENTIL	LANEY SHALE MEMBER	LANEY SHALE MEMBER	LANEY SHALE MEMBER	TOWER SS LENTIL	LANEY SHALE MEMBER
	LOWER GREEN RIVER GROUP	LANEY SH. MEMBER & LACUSTRINE FACIES OF CATHEDRAL BLUFFS RED BEDS MEMBER	LANEY SHALE MEMBER	LANEY SHALE MBR	NEW FORK TONGUE OF THE WASATCH FM	NEW FORK TONGUE OF THE WASATCH FM	WILKINS PEAK MBR	WILKINS PEAK MBR	WHITE SHALE BEDS	WILKINS PEAK MBR	UPPER UNIT	WILKINS PEAK MBR
				CATHEDRAL BLUFFS TONGUE OF THE WASATCH FM	NEW FORK TONGUE OF THE WASATCH FM	NEW FORK TONGUE OF THE WASATCH FM	WILKINS PEAK MBR	CATHEDRAL BLUFFS TONGUE OF THE WASATCH FM	GREEN SILTSTONE TONGUE OF THE WASATCH FM	CATHEDRAL BLUFFS TONGUE OF THE WASATCH FM	MIDDLE UNIT	CATHEDRAL BLUFFS TONGUE OF THE WASATCH FM
											LOWER UNIT	
		TIPTON SHALE MEMBER	TIPTON SHALE MEMBER	TIPTON TONGUE	FONTENELLE MEMBER	FONTENELLE TONGUE	TIPTON SHALE MEMBER	TIPTON TONGUE	TIPTON SHALE MEMBER	TIPTON TONGUE	TIPTON SHALE MEMBER	TIPTON TONGUE
WASATCH GROUP	BITTER CREEK GROUP	WASATCH FORMATION	WASATCH FORMATION		KNIGHT FORMATION	WASATCH FORMATION			WASATCH FORMATION	WASATCH FORMATION		

FIGURE 2. Chart showing the history of nomenclature for the Green River Formation in the Bridger Basin.

The terminology used in this report is essentially that of Bradley, Donovan, and Deardorff. However, I do not believe that the name Fontenelle is necessary to designate a mere continuation of the Tipton on the west side of the basin. The only difference between the two is that the unit becomes more clastic to the west and northwest as it approaches a source area. The Tipton Tongue of Bradley (1926) displays exactly the same characteristics in the northeast as it approaches the Wind River Mountains. I also believe that the name New Fork should be abandoned in favor of the name Cathedral Bluffs. The "New Fork Tongue" is essentially equivalent to the Cathedral Bluffs Tongue to the northeast, and has a similar genesis and lithology. The two are probably contiguous in the subsurface in the northern part of the basin. The only difference is that the New Fork is somewhat discontinuous, thinner, and the sediments had their source in the northwest and west rather than in the northeast.

The three Wilkins Peak subdivisions of Deardorff (1959) are simply called units. The lower and upper units may be the only two represented in the northern

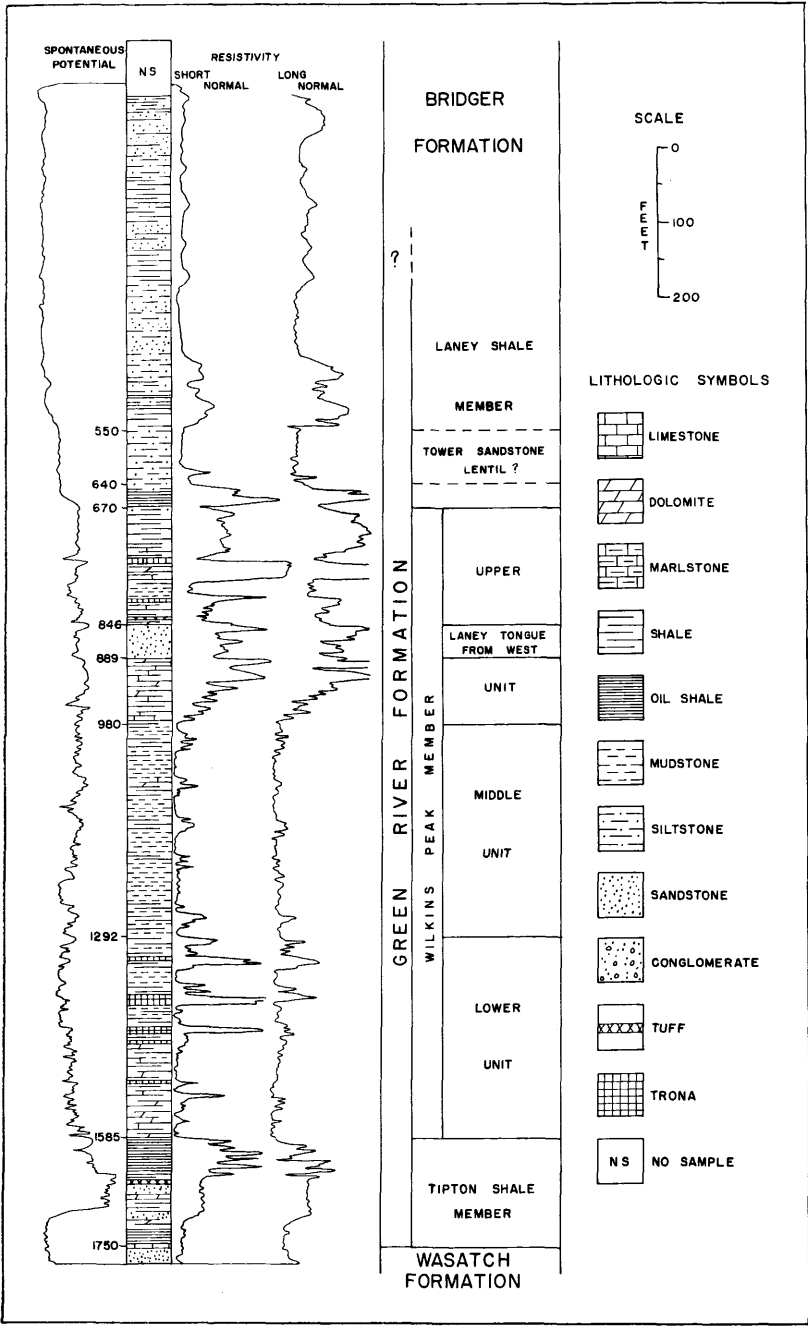


FIGURE 3. Type well of the Green River Formation, Bridger Basin. Diamond Alkali Co., No. 3. See Textoris (1960) for complete cutting and core description.

part of the basin, and the lower and perhaps the middle units are the only two present in the western part.

The Tower Sandstone Lentil has been retained in this report for convenience although Culbertson (1962) suggested abandonment. The Tower is not one continuous unit either horizontally or vertically, although Tower-like sandstones

TABLE 1

Names and locations of surface sections, Bridger Basin, Wyoming

Reference letter	Name	Location	Reference
A	Big Piney	Northern part of 28N 111W	After Donavan (1950, Pl. 11)
B	Hams Fork	29, 30, 32, 21N 114W	Measured by Bates and Textoris. See Textoris (1960, Appendix II) for description
C	Piedmont	2, 3, 14N 117W	Measured by Bates. See Textoris (1960, Appendix II) for description
D	Currant Creek	35 16N 116W	After Deardorff (1959)
E	White Mountain	3, 5, 6, 14N 106W	Measured by Deardorff and Textoris. See Textoris (1960, Appendix II) for description
F	Leucite Mountain	33, 34 15N 107W	After Bradley (1926, Pl. LIX)
G	Alkali Brook	3 21N 105W	
		NW part 24N 103W	
		Central part 25N 102W	After Bradley (1926, Pl. LIX)

TABLE 2

Names and locations of wells, Bridger Basin, Wyoming

Reference number	Name	Location	Reference
1	Diamond Alkali, 3	8 18N 108W	Type well. See Textoris (1960, Appendix I) for detailed cutting and core description.
2	Diamond Alkali, McKenna 1	6 18N 106W	
3	Diamond Alkali, 1	12 18N 112W	
4	California Dry Creek 1	6 14N 110W	
5	Diamond Alkali, Reid 1	24 16N 109W	Lithology from the American Stratigraphic Company
6	Diamond Alkali, Reid 2	32 17N 107W	
7	Diamond Alkali, Butler 1	12 18N 108W	
8	Diamond Alkali, Berger 1	28 20N 108W	
9	General Petroleum, Buckhorn 62-A-9	9 24N 109W	
10	Carter, Opal 1	34 22N 112W	
11	Mountain Fuel, Church Buttes 18	14 17N 112W	
12	Diamond Alkali, Findley 2	26 16N 110W	Lithology from the American Stratigraphic Company

do occur only in the lower 400 ft of the Laney Shale Member. Indeed, the beds are not quartzose but tuffaceous sandstones or even crystal tuffs (Bradley, 1959). Certainly, the bodies of sandstone are lenticular and not one lentil, but the beds are very conspicuous in the vicinity of the town of Green River and here I believe the name can be applied. In this report, then, I will use the Tower Sandstone designation for thick sandstone units near the base of the Laney in the Green River vicinity.

The electric and lithologic logs of the Diamond Alkali Company's No. 3 well (fig. 3) give a complete section for the eastern part of the basin, and show the resistivity and lithologic peculiarities of each unit. A complete description of the well cuttings (75 ft to 725 ft) and the core (725 ft to 1771 ft) can be consulted in Textoris (1960, Appendix I).

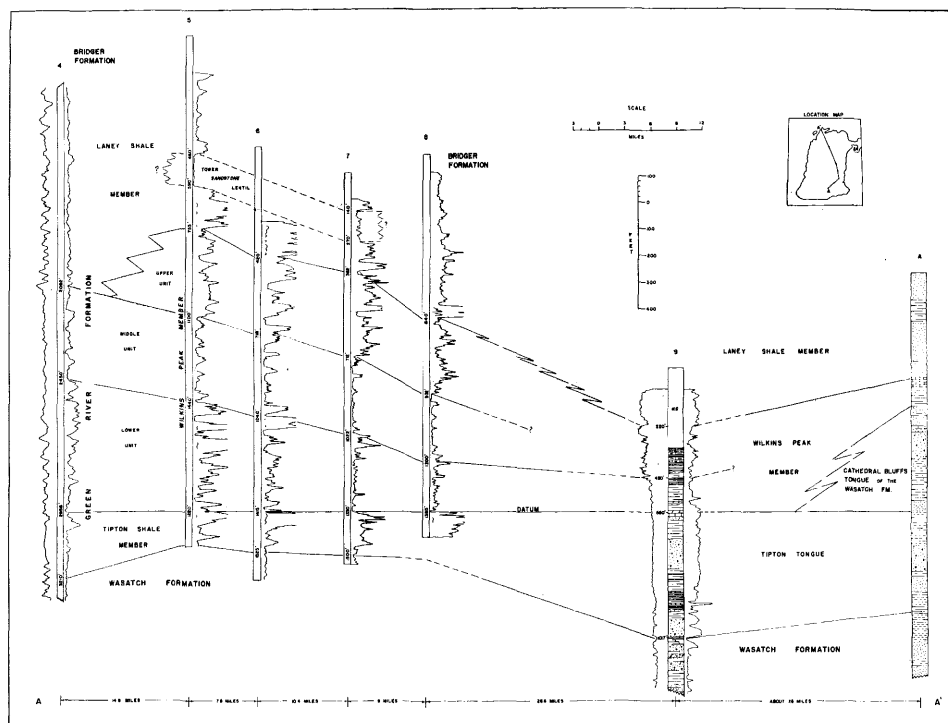


FIGURE 4. South-north cross section A-A' of the Green River Formation in the Bridger Basin. See figure 1 for line of section, tables 1 and 2 for section and well identification, and figure 3 for lithologic symbol key.

Basin-wide cross sections of the Green River Formation are shown in figures 4, 5, 6, and 7. Tables 1 and 2 give information about the surface sections and the wells used in this report.

Tipton Shale Member and Tipton Tongue

The Tipton Shale Member of the Green River Formation was named by Schultz (1920) for exposures in the vicinity of Tipton, a station on the Union Pacific Railroad located near the northern edge of the Washakie Basin. The Tipton is designated a tongue wherever the Cathedral Bluffs Tongue of the Wasatch Formation separates it from the main body of the Green River Formation.

In the Bridger Basin, this member consists primarily of brown and gray fissile shale (fig. 8), massive to varved oil shale, brown and gray sandstone, and brown and gray tuff, some of which has been analcitized. Thin beds of oölitic and arenaceous limestone are common. Bradley (1926) reported numerous calcareous algal reefs in the northeast part of the basin. Organic matter is abundant in some areas, occurring as low-grade lignite or as nuclei in sandstone concretions.

At the base of the Tipton is a persistent fossiliferous zone containing abundant *Goniobasis* and other gastropods, *Unio* and other pelecypods, and ostracods. This

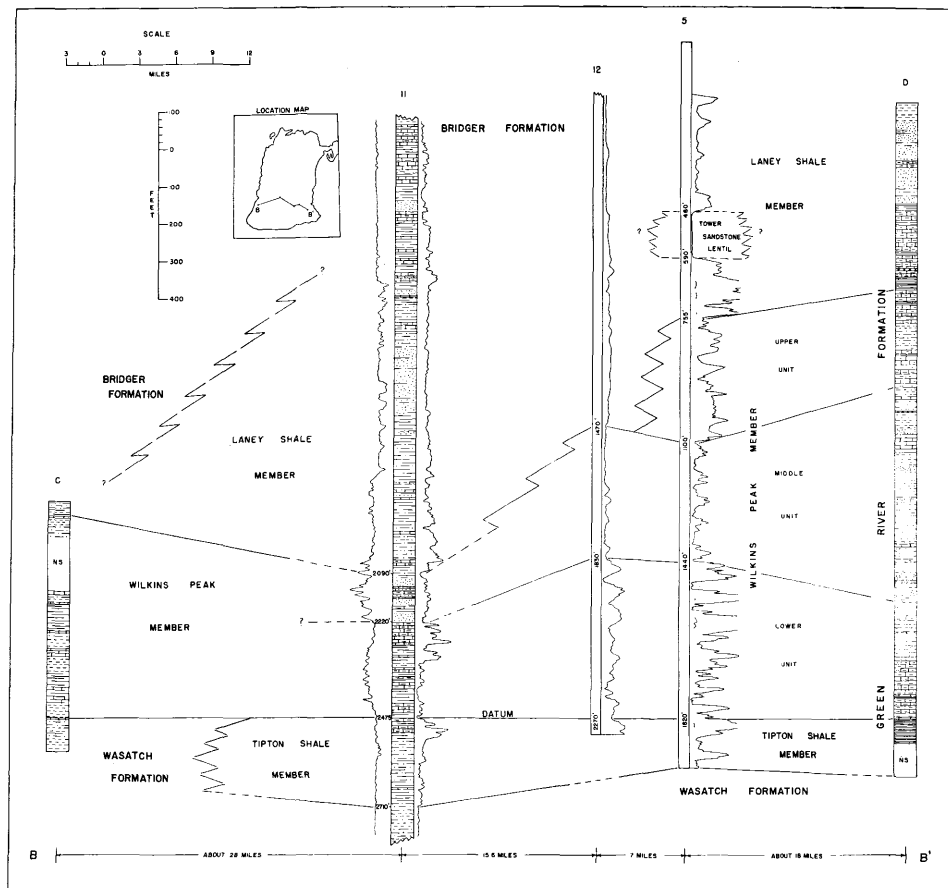


FIGURE 5. West-east cross section B-B' of the Green River Formation in the southern part of the Bridger Basin. See figure 1 for line of section, tables 1 and 2 for section and well identification, and figure 3 for lithologic symbol key.

zone is found in the subsurface as well as on the outcrop. It varies in thickness, and is found in both lacustrine limestone and near-shore sandstone and conglomerate. The zone probably represents a near-shore accumulation, deposited as Gosiute Lake (the name applied by King, 1878, to the lake which existed in southwestern Wyoming during the Green River Epoch) advanced over the Wasatch floodplains and coalesced with smaller ponds (Sears and Bradley, 1924; Deardorff, 1959). In some near-shore areas there are several of these zones, indicating a fluctuating shore-line.

The usual thickness of the Tipton is between 100 and 300 ft. Thicknesses of over 400 ft are not uncommon in the northern part of the basin, although Oriel (1961) would assign some of this footage to the Cathedral Bluffs.

The Tipton is the basal unit of the Green River Formation in the Bridger Basin (figs. 3-7). The Wasatch Formation underlies the Tipton nearly everywhere in the Bridger Basin. The Tipton crops out along most of the western side of the

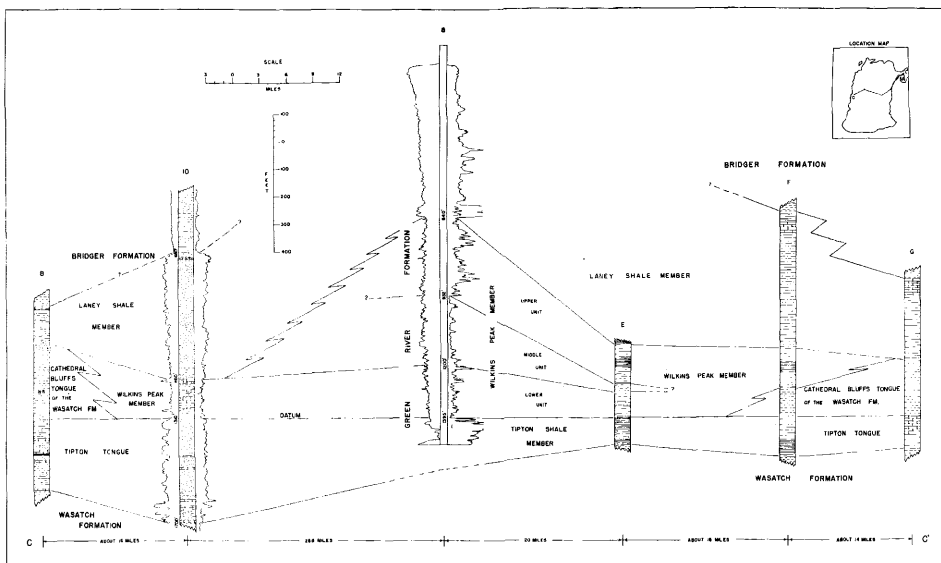


FIGURE 6. West-east cross section C-C' of the Green River Formation in the northern part of the Bridger Basin. See figure 1 for line of section, tables 1 and 2 for section and well identification, and figure 3 for lithologic symbol key.

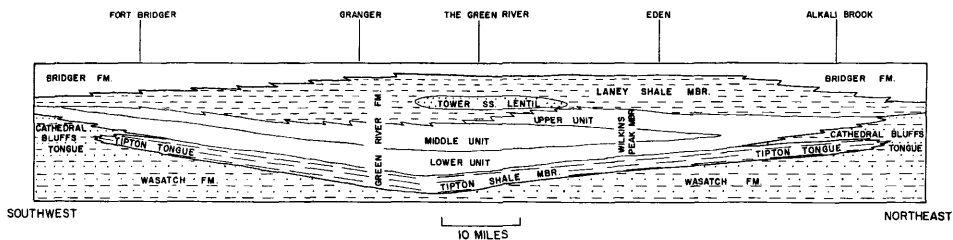


FIGURE 7. Diagrammatic cross section of the Green River Formation in the Bridger Basin from the southwestern corner to the northeastern. Vertical exaggeration about 42X.

basin and along all of the eastern side. In the northern and southwestern parts, it interfingers with the Wasatch Formation in the subsurface and does not crop out. In the south along the north flank of the Uinta Mountains, the entire Green River Formation is composed of sandstone and conglomerate, and the various units, although present, cannot be clearly differentiated.

The Tipton is readily separated from the Wasatch, which consists of green and red mudstone and brown and gray sandstone.

Throughout most of the basin, the Tipton is overlain by the light-gray shale and marlstone of the Wilkins Peak Member. The contact is not difficult to

identify in the surface or subsurface except where near-shore conditions prevailed.

In some well cores, thin beds of trona that are peculiar to the Wilkins Peak Member interfinger with strata typical of the Tipton.

On the electric log, the Tipton displays a distinctive resistivity curve. In the east and southeast, the high resistivity curve at the top of the Tipton represents oil shale. In the Carter (10) and General Petroleum (9) wells, the S. P. and resistivity curves show typical sandstone aspects. The resistivity of the Tipton as a whole contrasts strongly with the very low resistivity of the Wasatch mudstone and the low resistivity of the Wilkins Peak shale.

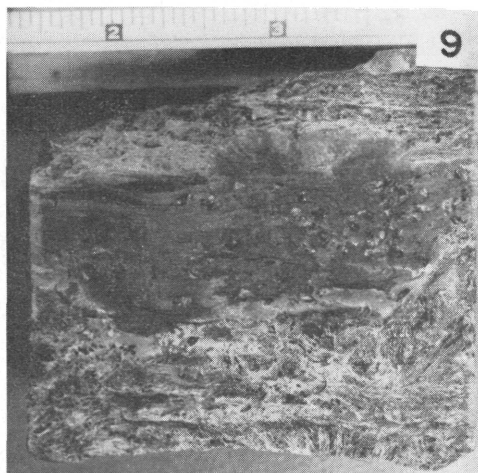


FIGURE 8. Gray fissile shale grading upward into a low-grade varved oil shale. Tipton Shale Member. Core from a depth of 1908 ft from the Diamond Alkali, 1 (3). Inch scale.

FIGURE 9. Brown massive to crystalline trona ($\text{Na}^2\text{CO}^3 \cdot \text{NaHCO}^3 \cdot 2\text{H}^2\text{O}$) (upper and lower parts of specimen), and black varved oil shale. The oil shale contains crystals of oil-stained shortite ($\text{Na}^2\text{CO}^3 \cdot 2\text{CaCO}^3$). Middle unit of the Wilkins Peak Member. Core from a depth of 1119 ft from the Diamond Alkali, Reid 1 (5). Inch scale.

A near-shore, cross-bedded sandstone and conglomerate facies of the Tipton is present on all sides of the Bridger Basin except the east. Here the member is represented by lacustrine shale and oil shale. This indicates that the Rock Springs Uplift was not positive enough to act as an important source of material from the east. Indeed, Lake Gosiute probably extended over the Uplift area and joined both the Bridger and Washakie Basins.

Donavan (1950) believed that in the northwestern part of the basin the Tipton represents a shore-line delta, and concluded that the Wyoming Range supplied the sediment for it. This Range was probably the source for the Tipton along the whole western side.

Bradley (1926) described the gradation of fluvial sediments near the Wind River Mountains southward into lacustrine sediments. An analogous relation

exists along the south edge of the basin, where oil shale passes into a sandstone and conglomerate facies as the member approaches the Uinta Mountains.

Wilkins Peak Member

The Wilkins Peak Member of the Green River Formation is of particular interest because it represents the saline phase of Gosiute Lake. Trona, shortite, gaylussite, and a host of other soda-rich saline minerals, some yet unnamed, are found in this member. Trona is present in quantities sufficient to justify mining, but the others occur in much smaller amounts. The Wilkins Peak is the only member of the Green River Formation that is not present in the Washakie Basin. There, its stratigraphic position is taken by the Cathedral Bluffs Tongue of the Wasatch Formation.

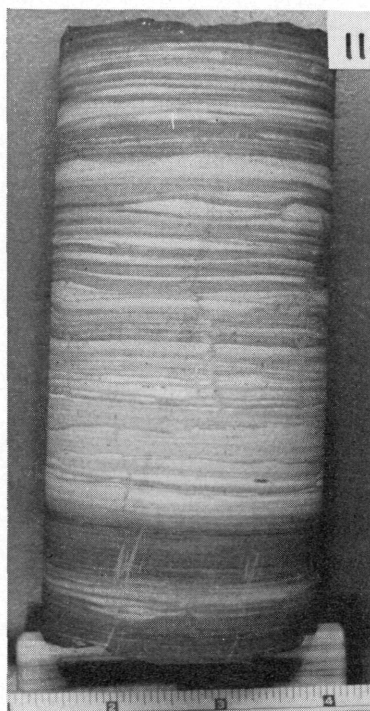
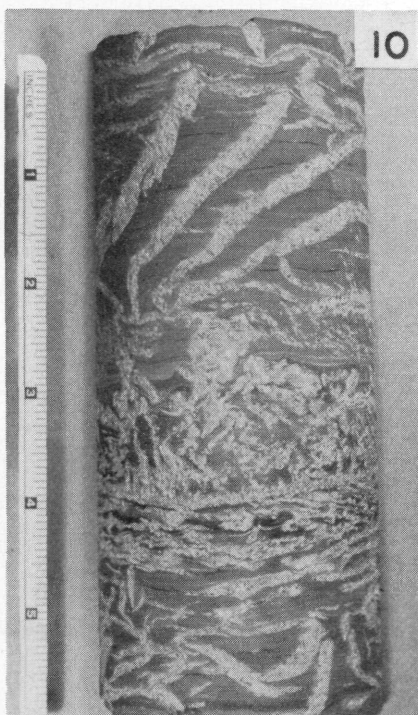


FIGURE 10. Greenish-gray shale containing abundant stringers of interlocking northupite crystals ($\text{Na}^2\text{CO}_3 \cdot \text{MgCO}_3 \cdot \text{NaCl}$). Some of the northupite concentrations appear to be syngenetic, others epigenetic. Note the disrupted bedding in the middle and upper parts of the specimen. Middle unit of the Wilkins Peak Member. Core from a depth of 1127 ft from the Diamond Alkali, Reid 1 (5). Inch scale.

FIGURE 11. Gray cross-laminated marlstone with interbedded light-gray tuff. Upper unit of the Wilkins Peak Member. Core from a depth of about 800 ft from the Diamond Alkali, Reid 1 (5). Inch scale.

The Wilkins Peak Member was named from typical exposures on Wilkins Peak, a hill seven miles east of the town of Green River, Wyoming (Bradley, 1959). At the type locality the member is about 900 ft thick, and is composed of light-gray marlstone, gray and green shale and mudstone, some light-gray siltstone and sandstone, and oil shale. Calcite pseudomorphs and molds of shortite are found on the outcrop. Shortite and other syngenetic evaporite minerals are found only in the subsurface (figs. 9–10, 12–13).

The outcrop of these finely-laminated strata makes a striking white and light-gray slope. The lithology and color of this member set it off from the underlying Tipton and from the overlying brown and gray strata of the Laney Shale Member. The only fossils so far found consistently in the Wilkins Peak are gastropods and ostracods. Algal reefs and algal encrusted logs have also been found along the western and northwestern margins of the basin, and indicate near-shore conditions (Donavan, 1950).

The Wilkins Peak thickens to more than 1100 ft to the south and southwest of the type locality. Approximately 20 miles to the southwest and 15 miles to the west, however, the Wilkins Peak begins to thin because the upper unit interfingers with the Laney Shale Member. As the southwestern and western mar-

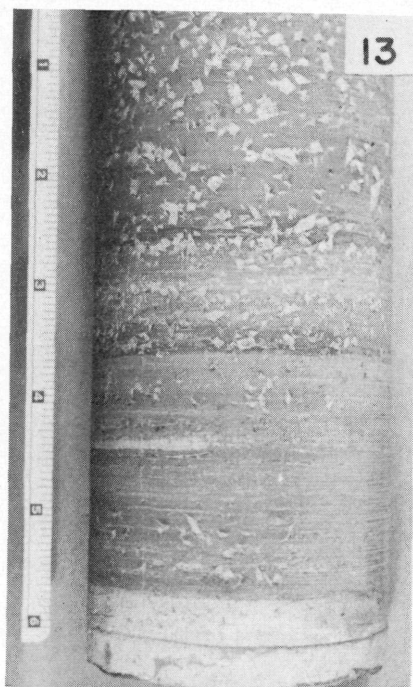
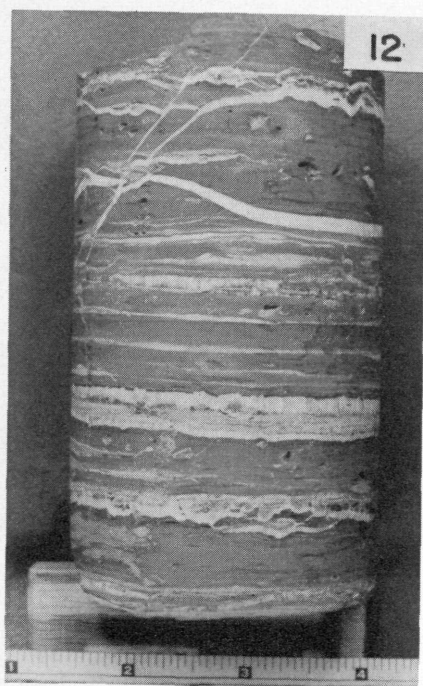


FIGURE 12. Laminae and very thin beds of gaylussite ($\text{Na}^2\text{CO}^3 \cdot \text{CaCO}^3 \cdot 5\text{H}^2\text{O}$) in a gray mudstone. Note gaylussite cutting the bedding in the upper part of the specimen. Upper unit of the Wilkins Peak Member. Core from a depth of 517 ft from the Diamond Alkali, McKenna 1 (2). Inch scale.

FIGURE 13. Gray mudstone containing abundant white to colorless shortite crystals. A thin light-gray tuff is at the base of the specimen. Upper unit of the Wilkins Peak Member. Core from a depth of 521 ft from the Diamond Alkali, McKenna 1 (2). Inch scale.

gins of the basin are approached, the middle unit is partially or completely replaced by the Laney, and the lower unit is partially or completely replaced by the Cathedral Bluffs Tongue (figs. 4-7).

Relationships in the subsurface to the north are less well known because of lack of control. It is suggested that the Wilkins Peak also thins somewhat due to the interfingering mentioned above, but most of the thinning is probably because the middle unit pinches out and because of increasing distance from an area of more subsidence in the south. The member does not crop out on the north-

central margin of the basin (McGrew and Berman, 1955). Thus, the thickest and best developed sections of the Wilkins Peak are in the eastern part of the basin.

A brief description of each of the three units of the Wilkins Peak, which were defined by Deardorff (1959), follows. Millice (1959) and Culbertson (1961) set boundaries of the three units somewhat differently, but all are in general agreement.

Lower unit.—The lower unit is composed of gray and green shale, marlstone, and some low-grade oil shale, green mudstone, and gray to brown tuff. Some of the tuff has been analcitized. In the subsurface these lower unit beds contain amber to dark-brown trona beds and abundant shortite in both single crystals and masses. The first halite reported from the Bridger Basin was discovered in this unit in the Diamond Alkali, Reid 1 well (5).

This unit is probably the only part of the Wilkins Peak Member that appears along the western margin of the basin. The middle unit may also be present in some areas in the west. In the northwest, the lower and upper units probably merge. I am not certain whether all three units are present in the northeast, but it is suggested that the same relationship holds there as in the northwest.

A typical resistivity curve for the lower unit is shown in figure 3. Here only a small amount of trona affects the resistivity.

Middle unit.—This unit was named the green siltstone tongue of the Wilkins Peak Member by Deardorff. It is composed of green and tan siltstone, sandstone, and green silty mudstone which alternates with green and gray shale. The unit makes a series of distinct dark bands on the outcrop, between the uniformly light-colored upper and lower units. The coarser material is usually lenticular and cross-bedded. Two types of cross-bedding have been observed: (1) large-scale bedding depicting channel and fill, and (2) small-scale laminations representing lacustrine wave and current agitation. The former is well exposed in fresh road cuts on U. S. route 30 near the type locality of the Wilkins Peak.

Whereas the lower and upper units are primarily playa-lacustrine deposits, the middle unit represents an alternating shallow lacustrine and floodplain deposit. The lacustrine facies are represented by shale, the channel facies by cross-bedded sandstone and siltstone, and the floodplain and shallow-water facies by mudstone. The mudstone is similar to that of the Wasatch or Cathedral Bluffs, and gives the same type of resistivity curve on electric logs. Trona and other saline minerals are found only in the shale and mudstone (figs. 9, 10).

In the southwestern and western parts of the basin, the middle unit is partially or completely replaced by the Laney. The suggestion that the unit thins and pinches out in the northern part of the basin is based partly on its observed thinning and possible disappearance to the northeast along the outcrop, and partly on subsurface evidence in the General Petroleum, Buckhorn 62-A-9 well (9). This accords with the suggestion of Deardorff (1959), that the middle unit represents the rapid erosion and filling of the basin due to deformation along the north flank of the Uinta Mountains.

Upper unit.—The upper unit, or white shale beds of Deardorff, consist of light gray and light green calcareous to dolomitic shale and marlstone (fig. 11), some oil shale, and occasional tuff similar to that of the preceding units. Like the other two units of the Wilkins Peak, it contains abundant evaporite minerals in the subsurface (figs. 12, 13).

This unit represents the last of the saline phase, and is confined to a long linear north-south belt in the eastern quarter of the basin. Northward, it probably fans out horizontally to emerge along the northwest margin of the basin.

The resistivity of this unit is high, because of the abundance of carbonate beds.

Cathedral Bluffs Tongue of the Wasatch Formation

The Cathedral Bluffs Tongue was named by Schultz (1920) from exposures along the north rim of the Washakie Basin. In the Bridger Basin the Cathedral

Bluffs is represented by green, gray, deep red, buff, and yellow mudstone, sandstone, conglomerate, and thin calcareous algal reefs. The coarser rocks are commonly lenticular and cross-bedded. The tongue erodes to brightly colored badlands where it is thick enough to be prominent. Donavan (1950) reported numerous turtle bones, fish teeth, and two mammalian teeth from this unit in the northwest part of the Bridger Basin. He also reported shrinkage cracks filled with syngenetic gypsum.

Cathedral Bluffs lithology is quite different from that of the underlying Tipton Tongue and the overlying Wilkins Peak and Laney Members of the Green River Formation. However, difficulties in recognizing the contacts have been encountered along the western margin of the basin where the whole section represents a near-shore environment. Oriel (1961) recognized two major Cathedral Bluffs Tongues here.

Tongues of Cathedral Bluffs strata are small and somewhat discontinuous along the western and northwestern margins. None of these tongues penetrate more than a few miles into the basin. No Cathedral Bluffs was found in the wells available for study, probably because none of the wells were drilled near enough to the margins of the basin. Where present, however, the Cathedral Bluffs should display a resistivity curve similar to that of the Wasatch Formation.

In some areas the Cathedral Bluffs tongues interfinger with the lower unit of the Wilkins Peak Member and completely replace it (fig. 6). Elsewhere the Cathedral Bluffs is probably the equivalent of the upper and lower units of the Wilkins Peak (figs. 4 and 6). In the southwest the Tipton Tongue grades into the Wasatch sediments, and the Cathedral Bluffs cannot be differentiated. In the north both the Tipton and the Wilkins Peak are represented by the Wasatch Formation (McGrew and Berman, 1955).

The Cathedral Bluffs Tongue is not present along the north flank of the Uinta Mountains, or along the eastern outcrop. According to Sears and Bradley (1924), the large Cathedral Bluffs Tongue from the east probably had its maximum westward extent to approximately the north-south axis of the Rock Springs anticline, from where it has been eroded. The tongue has been traced, however, around the north end of the Rock Springs Uplift by Schultz (1920) and Bradley (1926) to the northeastern part of the Bridger Basin. This tongue from the east is probably the lateral equivalent of the Wilkins Peak (Bradley, 1959), the smaller Cathedral Bluffs tongues around the margins of the basin (Gazin, 1952), and the lower part of the Laney that interfingers with the Wilkins Peak.

The Cathedral Bluffs Tongue, or Tongues, represent fluvial, floodplain, and beach deposits that encroached upon the basin from all directions but the south.

Laney Shale Member

The Laney Shale Member of the Green River Formation was named by Schultz (1920) for typical exposures along the Laney Rim, which forms the north edge of the Washakie Basin. In the Bridger Basin, this member is composed of carbonaceous and fossiliferous brown and gray shale, siltstone, sandstone, marlstone, massive to varved oil shale (fig. 14), and thin limestone, analcite beds, and analcitized and unaltered tuff and tuffaceous sandstone. Indeed, admixtures of tuff are common throughout the whole member. The carbonates often contain oölites and pisolites. The Laney does not contain any syngenetic evaporite minerals except in the subsurface along the facies contact with the Wilkins Peak.

The Laney is very fossiliferous; in fact, plant fragments are so numerous that Powell (1876) named this unit the "Plant Beds" of his Upper Group. It also contains abundant ostracods, fish, mollusks, and algal reefs.

The near-shore and fluvial characteristics of the Laney in the northern part of the basin have been set forth in detail by Bradley (1926), Donavan (1950), and McGrew and Berman (1955). The Laney is the only member of the Green River

Formation that crops out in the north-central part of the basin, where it lies on sediments that are probably the equivalent of the Cathedral Bluffs Tongue. In the southern, southwestern, and western parts of the basin, the Laney sediments appear to represent an encroaching shallow-water deposit, marginal to the deeper-water Wilkins Peak sediments. In the east and southeast, however, the Laney represents a deeper-water environment, as shown by the varved oil shales.

The contact between the Laney and the Wilkins Peak is easy to identify, especially in the eastern and southeastern parts of the basin, where the base of the Laney is composed of brown-weathering oil shale. High resistivity curves from the wells in the area show the presence of this basal oil shale in the subsurface, also. The contact between the Laney and the overlying Bridger Formation, how-

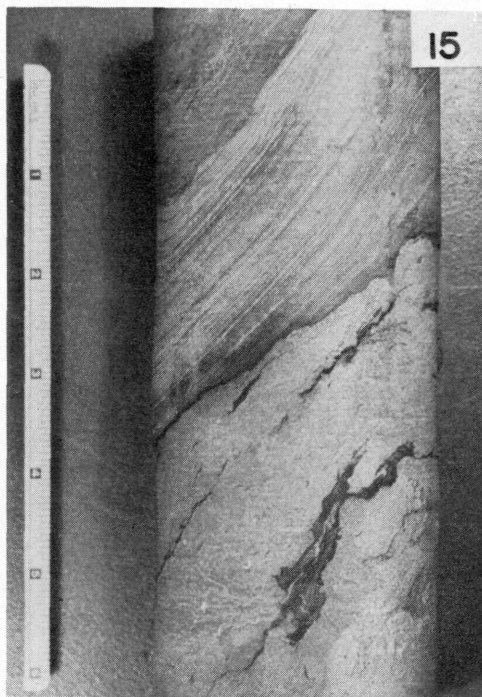
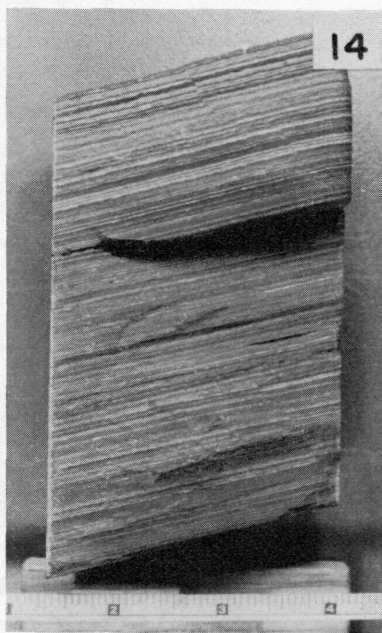


FIGURE 14. Black and buff varved oil shale (varved kerogenous dolomite). Minor faults occur in the upper and lower right parts of the specimen. The varves attain a 25° dip. Laney Shale Member. Core from a depth of 315 ft from the Diamond Alkali, McKenna 1 (2). Inch scale.

FIGURE 15. Brown and gray carbonaceous tuffaceous sandstone. The dark irregular bands that parallel the bedding in the lower half of the specimen are caused by organic matter. The beds dip 55°. Laney Shale Member, probably the Tower Sandstone Lentic. Core from a depth of 243 ft from the Diamond Alkali, McKenna 1 (2). Inch scale.

ever, is difficult to distinguish because it is transitional. The Bridger is composed of fossiliferous gray and green mudstone, siltstone, sandstone, and tuff. This sequence represents alternating fluvial and lacustrine environments. A general contact can be drawn for surface sections on the basis of dissimilar topography and weathering color of the two units. The Laney weathers buff and forms regular slopes, whereas the Bridger weathers green and gray and displays bad-

land topography. This contact has not been found with certainty in the subsurface. In the cross sections, the Bridger Formation is indicated near the top of the well, if the well was begun in that formation.

In figure 5, a partial facies contact is drawn between the Laney and the Bridger. This is based on the following statement by Nace (1939):

Before the Morrow Creek [Laney] lake had reached its maximum expansion northward, *Bridger time had begun* [Nace's emphasis]. On the south side of the Green River Basin [Bridger Basin], in the type locality of the Bridger formation, fluvial sediments of Bridger lithology began to accumulate.

Tower Sandstone Lentil.—Near the base of the Laney, and in places coincident with the base, are a peculiar series of lenticular bodies of tuffaceous sandstone. They crop out in a small area around the town of Green River. Isolated remnants of this resistant brown rock cap small peaks in this area, and form "towers", from which the Tower Sandstone received its name (Powell, 1876). For many years it was described as a coarse-grained fluvial sandstone. Recently, Bradley (1959) reported that the unit is primarily a fine-grained crystal tuff. Culbertson (1962) described it as a reworked crystal tuff with fluvial admixtures (fig. 15).

The Tower Sandstone Lentil attains thicknesses of about 250 ft near the type locality. The "lentils" are discontinuous, thin rapidly, pinch out, and reappear. Seldom is this unit horizontally bedded. Usually the bedding is contorted and steeply dipping. Differential compaction and primary down slope movement (Rapp, 1962) are two methods by which the peculiar structure can be explained. The Tower is found both conformable and unconformable with the strata above and below.

The areal distribution of the Tower is not known. A few miles north of the Diamond Alkali, Reid 1 (5) in the valley of Blacks Fork, there appears to be an outcrop of Tower Sandstone. It also crops out in several areas south of the town of Green River along the eastern escarpment.

The Tower has not been definitely identified in the subsurface by the writer. The high-angle bedding displayed by the tuffaceous sandstone in the Diamond Alkali, McKenna 1 (2) (fig. 15) is suggestive of Tower bedding. The siltstone interval from 550 to 640 ft in the Diamond Alkali, 3 (1) is in the correct stratigraphic position to represent the Tower. The resistivity curve for this interval does not resemble that of a quartzose siltstone and may represent a tuffaceous variety. A similar zone can be correlated in the Diamond Alkali, Reid 1 (5) and Butler 1 (7) wells.

GEOLOGIC HISTORY

Exact correlation of contemporaneous sediments is difficult. Although ash falls were common throughout the evolution of Gosiute Lake, most of the ash formed thin beds or became admixed with the normal sediments. Tuff beds up to 1 ft thick have been recognized, but they cannot be traced very far at the surface because of poor or covered exposures, and in megascopic subsurface work they have usually been misinterpreted as siltstone. Through careful future work, however, one or more beds could probably be discovered and used throughout most of the basin.

As Wasatch sedimentation came to an end throughout the major part of the Bridger Basin, small isolated lakes began to form on the vast floodplain complex. The general slope of the basin floor was probably to the south or southeast (Nace, 1939). Gosiute Lake in the Bridger Basin probably developed first in the southeastern part, slowly advanced to the west and north, and coalesced with the smaller lakes. Tipton sediments spread over the area of the Rock Springs Uplift, and made the Bridger and Washakie Basins contiguous. Meanwhile, Wasatch sedimentation continued in the southwestern and northern parts of the basin.

Throughout the evolution of Gosiute Lake, subsidence occurred mainly in the southeastern part of the basin. Oil shale and varved shale indicate that deeper water persisted in this part of the basin than in the western and northern parts during Tipton sedimentation. Shallow water marginal sandstone and conglomerate were deposited along the north flank of the Uinta Mountains at this time, and throughout the evolution of the lake. Near-shore conditions prevailed along the western margin and along the northern part of the basin. The relatively thick and coarse sediments that were deposited in these areas came from the Wyoming Range and the Wind River Mountains respectively. The climate during the initial stage of Gosiute Lake was humid.

Gradually the climate became arid, and the lake contracted and became shallower. Tongues of fluvial sediments (Cathedral Bluffs) advanced over the marginal Tipton deposits from the southwest, west, and north. A large Cathedral Bluffs tongue advanced west from the Washakie Basin, and extended into the area now occupied by the Rock Springs Uplift or even slightly farther west. The saline phase of Gosiute Lake set in, and trona, halite, shortite, and other soda-rich minerals grew in the calcareous and dolomitic muds that now form the lower unit of the Wilkins Peak Member.

The climate then became somewhat more moist, and the Cathedral Bluffs tongues along the western margin were overlapped by the lower unit of the Wilkins Peak (fig. 7).

Deformation along the north flank of the Uinta Mountains caused Gosiute Lake to become a vast mudflat. The deformation provided the coarser sediments that filled and spread over most of the basin to form the middle unit of the Wilkins Peak. The effects of this filling probably did not extend to the northern part of the basin. Periodic inundations formed lacustrine facies in which more evaporites formed. Meanwhile, carbonaceous near-shore Laney sediments began to accumulate in the southwestern and western parts of the basin, and to advance eastward. Cathedral Bluffs sedimentation continued in the north and probably east of the Rock Springs Uplift.

Following the basin-filling, Gosiute Lake became deeper again and sediments of the upper unit of the Wilkins Peak were deposited. Environmental conditions were probably similar to those that prevailed during the deposition of the lower unit. Evaporites and oil shale formed along with the shale and marlstone. In the northern part of the basin, the lower and upper units merged. The climate continued to become more humid, and the Laney sediments continued to advance eastward. The Cathedral Bluffs tongues in the north and east began to be overlapped by the upper unit of the Wilkins Peak. Typical Bridger sediments probably began to accumulate in the southwest.

During the waning stages of the saline phase, sediments of the upper unit of the Wilkins Peak were deposited in a long north-south belt along the eastern quarter of the basin. Northward, the sediments spread out to the northwest.

The climate gradually became humid enough to terminate the saline phase. Cathedral Bluffs sedimentation came to an end in the Bridger Basin and Laney sediments spread over the deposits of both the Cathedral Bluffs and the upper unit of the Wilkins Peak.

Both coarse-grained and fine-grained carbonaceous Laney materials were deposited, in alternating shallow and deeper water. Meanwhile, the fluvial Bridger deposits continued to form and maintained an eastward and northward advance until the lake basin was filled in.

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